CLASSIFICATION ~~SECRET~~ SECRET FOR OFFICIAL USE ONLY

CENTRAL INTELLIGENCE AGENCY
INFORMATION FROM
FOREIGN DOCUMENTS OR RADIO BROADCASTS

REPORT

CD NO.

STAT

| | | | |
|---|---|---|---|
| COUNTRY | USSR | DATE OF INFORMATION | 1948 |
| SUBJECT | Scientific - Geophysics, meteorology | | |
| HOW PUBLISHED | Bimonthly periodical | DATE DIST. | 1 SEP 1950 |
| WHERE PUBLISHED | Leningrad | NO. OF PAGES | 7 |
| DATE PUBLISHED | 1948 | SUPPLEMENT TO REPORT NO. | |
| LANGUAGE | Russian | | |

F000
FDD/OC
AUG 7 1956



THIS IS UNEVALUATED INFORMATION

SOURCE Meteorologiya i Gidrologiya, No 3, 1948.

## MAXIMUM HEIGHTS OF ASCENT OF SPHERICAL RUBBER BALLOONS

N. P. Vorob'yev

In clear weather, one-point observations on pilot balloons sometimes last for long periods. Processing of these observations indicates heights of ascent of 30-50 kilometers and more. As a rule, the wind data obtained by station observers for these heights is enciphered in telegrams and eventually published as observed and trustworthy information.

These data differ sharply from data compiled for the usual heights of 10-15 kilometers, and therefore should be subjected to closer scrutiny. Is there a limit to the height of ascent and what are the limiting factors? What is the explanation for such prolonged observations? Many questions on this subject have been received recently from stations and observatories, especially from those in the south. To answer these questions, we first consider the existing types of envelopes.

Rubber envelopes are usually considered to be ideally elastic. This is a convenient description, but does not actually describe the state of the rubber skin. It has now been established that temperature limits for highly elastic properties exist for all types of vulcanized rubber (Zayonchkovskiy, A. D., Technology of Leather Substitutes, Gizlegprom, 1940; Treloar, L. R., Reports on Progress in Physics, Vol IX, pp 113-136, 1943.) The lower limit is associated with the transition of rubber molecules into the crystallic or vitreous-like state, while the upper limit is connected with the transition into the state of a viscous fluid. Noninflated rubber passes from the amorphous to the crystallic state at 10 degrees centigrade and lower. The crystallization speed increases in stretching. Crystallic formations develop during prolonged storage of rubber as well as during cooling and expansion. Crystallization does not cover the entire mass; the crystallic and amorphous forms of rubber are found under certain conditions in unstable equilibrium, with the amorphous part smaller in inflated than in noninflated rubber. Changes in the phase state of molecules (crystallization) reduce elongation and increase tension in the rubber skin.

FOR OFFICIAL USE ONLY SECRET

CLASSIFICATION ~~SECRET~~

| | | | | | | DISTRIBUTION | | |
|---|---|---|---|---|---|---|---|---|
| STATE | X | NAVY | X | NSRB | | | | |
| ARMY | X | AIR | X | FBI | | | | |

STAT

At about 70 degrees below zero centigrade, rubber molecules enter the vitreous-like state, in which rubber becomes friable with practically no stretch, and sharply increases its ultimate strength.

Rubber balloons in flight are subjected to both low temperatures and tensile deformations. Decrease in the "stretching coefficient" (Kratnost' rastyazheniya) and increase in stress under negative temperatures both vary considerably, depending upon rubber type, ingredients, degree of vulcanization, etc. Thus, the degree to which rubber envelopes approximate ideally elastic envelopes may vary widely for different types of envelopes.

Assuming that the envelopes are ideally elastic and that the temperature of hydrogen during ascent is the same as that of the surrounding air, we obtain the well known formula:

$$D_0^3 : D^3 = G : G_0$$

where $D_0$ and $G_0$ are envelope diameter and air density at the surface (before ascent) and D and G are the same quantities at a certain level. Since $D_0$ and $G_0$ are constants for each practical case, the limiting (bursting) diameter D must be maximum for maximum ascent. /NOTE: This simple formula merely states mathematically that the buoying force of the atmosphere on the balloon is always constant./

Thus, the height of ascent of ideally elastic envelopes is limited by the elastic properties of the rubber, the size of the bursting diameter, or the maximum (bursting) stretching coefficient. This conclusion, although long accepted, is not the complete solution of the problem. We will show that the strength of the rubber skin is also an essential factor in determining the maximum height of ascent of real balloons.

The existing types of envelopes can be divided into the following categories:

1. Envelopes whose properties approach those of envelopes made of nonvulcanized rubber. These envelopes are soft and have little strength; in flight they have fixed lift and burst at low altitudes.

2. Envelopes whose properties are close to ebonite envelopes. These envelopes have a hard, thick, dense skin and stretch only under great stress; in flight they have decreasing free lift and burst at low altitudes.

3. Envelopes which have high elasticity and strength and maintain fixed free lift in flight. These envelopes are quite soft. They are basic in aerological practice. The volume of these envelopes in flight is usually considered inversely proportional to air density.

4. Envelopes which have elastic properties at the beginning of flight and harden at the end of flight. The free lift in these balloons begins to decrease at a certain height and in some cases reaches zero; that is, the pibal levels off in air. Such cases are rare in natural latex (or caoutchouc) envelopes, but are common in envelopes made from sovprene (a synthetic chloroprene rubber.)

5. Envelopes having defects in the skin which form one or several persistent air holes in flight. The free lift in these balloons begins to decrease after formation of the air hole. They may level off and even drop slowly.

Air holes in latex, seamless balloons have recently become more common as a result of both the properties of the latex and production technology.

SECRET

SECRET



Several computations are required to determine maximum heights of ascent. We begin with calculations of maximum heights for ideally elastic envelopes which can be considered as including the envelopes in category 3. The calculations will be made for the international standard atmosphere, which is accepted everywhere for design calculations (Yur'yev, B. N., Experimental Aerodynamics, Oboronizdat, 1939).

Table 1

| Height (km) | Ratio of Diameters ($D:D_0$) | Lift per Cu M of Hydrogen (gr) | Height (km) | Ratio of Diameters ($D:D_0$) | Lift per Cu M of Hydrogen (gr) |
|---|---|---|---|---|---|
| 0 | 1.0000 | 1,100 | 30 | 4.0650 | 16.4 |
| 2 | 1.0677 | 905 | 35 | 5.2770 | 7.5 |
| 5 | 1.1853 | 660 | 40 | 6.8587 | 3.3 |
| 10 | 1.4376 | 370 | 45 | 8.9366 | 1.5 |
| 15 | 1.8501 | 174 | 50 | 11.7096 | 0.66 |
| 20 | 2.4062 | 79 | 55 | 15.1057 | 0.32 |
| 25 | 3.1279 | 36 | | | |

The relative variation of pilot balloon diameter with height is shown in Table 1. For heights about 20 kilometers, the temperature was considered to be constant (56, 50 degrees) /sic/.

Latex, seamless envelopes produced by a plant of GUGMS (Main Administration of the Hydrometeorological Service) have the aeromechanical indices shown in Table 2 (Instructions to Hydrometeorological Stations and Posts, No 4, Part 1, pp 13, insert, 1944).

Table 2

| Envelope No | Weight (grams) | Diameter, Non-inflated (cm) | Maximum Bursting Diameter D (cm) |
|---|---|---|---|
| 1 | 12 2 | 8 | 40 |
| 2 | 36 4 | 17 | 80 |
| 3 | 80 5 | 25 | 120 |
| 50* | 360 40 | 60 | 230 |



SECRET

SECRET

When Filled With Hydrogen

| Envelope No | Limiting, Bursting, Stretching Coefficient | Initial Diameter $D_0$ (cm | Free Lift A | Vertical Speed W (m/min) | Height of Ascent (km) |
|---|---|---|---|---|---|
| 1 | 5 | 37-38 | 14-22 | 100-120 | 2 |
| 2 | 4.7 | 64-67 | 110-140 | 160-175 | 5 |
| 3 | 4.8 | 80-83 | 205-250 | 200-220 | 10 |
| 50* | 3.8 | 153-156 | 1,800 | 300-400 | 10 |

*Envelope No 50 was taken out of production in January 1945 and replaced by envelope No 100 which is made from sovprene latex.

By using these tables, we can calculate the maximum stretching coefficient of envelope No 2 to ascend to 15 kilometers (for a norm of filling with hydrogen according to Table 2.)

For 15 kilometers we find the ratio to be $D:D_0 = 1.85$ in Table 1. For envelope No 2, average $D_0 = 66$ centimeters (Table 2). This means that a maximum (bursting) diameter of $D = 66 \times 1.85 = 122$ centimeters is required for ascent to 15 kilometers. This bursting diameter corresponds to a maximum (bursting) stretching coefficient of $K = 122/17 = 7.2$.

Similar calculations for envelope 3 reveal that the bursting diameter for a 20-kilometer ascent is $D = 197$, or a maximum stretching coefficient of $K = 197/25 = 7.9$.

In order to raise envelope No 20 (with a radiosonde) to 10 kilometers, we need a bursting diameter $D = 370$ centimeters, which corresponds to a stretching coefficient of $K = 370/60 \approx 6.2$.

One of the leaders of the rubber balloon industry says that only the best samples of latex balloons of average size have stretching coefficients of 7-7.5 and that only the best of large size have 6. In practice, this figure is 5-5.5 for the first envelopes, and 4-4.5 for the second. Similar results were obtained by the author in numerous tests of envelopes at a plant of the GUGMS.

Dines (The Meteorological Magazine, 1929) writes that he tested many English envelopes and obtained stretching coefficients of 7.5 only for the best samples. Coefficients about 5.5 were not obtained under flight conditions.

The American balloons, Dagex No 100 (weight 100 grams), produced by the Dewey and Almy Chemical Company, have uninflated diameter of 36 centimeters and bursting diameter of 230 centimeters, giving them a stretching coefficient of 6.4 (Bulletin of the American Meteorological Society, Vol 18, No 11, 1937). /NOTE: 230 = 36 x 6.4/.

English radiosonde balloons weighing 700 grams, produced by Guide Bridge Rubber and Company, have uninflated diameter of 115 centimeters and bursting diameter of 520 centimeters; i.e., a stretching coefficient of 4.5. For prewar Soviet balloons, stretching coefficient 5 was planned for envelope No 5 and coefficient 4.5 for envelopes Nos 10, 15, and 20. The coefficient was higher in practice, but did not exceed 7 for the first envelopes and 6 for the second.

STAT

Thus, we can conclude from many tests that the very best fresh latex envelopes No 1 only rarely have 8-9, the maximum stretching coefficient (which corresponds to an altitude of 6 kilometers); envelopes No 2 and 3's corresponding figures are 7-8 (giving an altitude of 15 kilometers for No 2, 20 kilometers for No 3); and No 50 has 6-6.6 (20 kilometers). At this time, the industry does not produce envelopes with higher stretching coefficients.

The sharp discrepancy in maximum (bursting) stretching coefficient between the best envelope samples and those shown in Table 2 for mass-produced envelopes is accounted for by defects in production technology and aging of the rubber skin.

What in general are the maximum heights for ideally elastic balloons whose volume in flight is inversely proportional to air density? We taken an extreme case for illustration, namely:

1. We assume that an envelope filled with hydrogen levels off in air in the "noninflated" state; i.e., the stretching coefficient is unity. Calculations show that we will then have an envelope diameter of 200 centimeters and a weight of 5,000 grams for a skin 0.040 centimeters thick. Accordingly, we will have an envelope diameter of 130 centimeters and a weight of 1,220 grams for a skin 0.025 centimeters thick.

2. We assume that this balloon is filled with hydrogen to a stretching coefficient of 1.1 (i.e., to 110 percent of the noninflated diameter) for flight. The free lift will then be 1,600 grams, enough to lift a radiosonde, for the first envelope. The calculated free lift of 380 grams for the second ballon is insufficient even for normal pibal observations (the vertical speed of the balloon is very low).

3. If the maximum stretching coefficient of the first envelope is 6, the bursting diameter D will equal 200 x 6 = 1,200 centimeters. Since $D_0$ equals 200 x 1.1 = 220 centimeters, the ratio $D:D_0$ equals 5.45. By interpolation in Table 1, we find an altitude of 36 kilometers for the value 5.45.

Thus, the maximum altitude which can be reached by the best ideally elastic large envelopes does not exceed 35 kilometers for radiosondes and pilot balloons. The maximum stretching coefficients (6-8) assumed in the calculations can be obtained for large envelopes only when they are made from high-quality natural or synthetic latex (neoprene).

How can we explain the prolonged one-point pibal observations which give heights of 30-50 kilometers for ordinary balloons? This could be observed only when the envelopes used belong to the 4th category of our classification. Actually, if we admit the possibility of complete balancing of the pilot balloon in the atmosphere, it can remain in this suspended state for long periods because hardening of the envelope is accompanied by increase in strength. Thus, with envelopes of the 4th category, the observer would record for this period some fictitious height of the most fantastic proportions. /NOTE: Apparently, the observer assumes that his balloon rises continuously, forgetting possible "balancing"./

To evaluate the approximate heights at which such balancing might occur for various envelopes, first assume that envelope No 2 rises, expanding until it reaches 5 kilometers in flight, and continues to rise maintaining constant volume (D = 80 centimeters, according to Table 2) until free lift has completely disappeared.

STAT

Dividing the weight of the envelope (36 grams) plus the weight of the hydrogen (20 grams) by the volume, 0.272 cubic meters, we obtain lift of 1 cubic meter of hydrogen equal to 244 grams. After interpolation in Table 1, we find a balancing height of 13 kilometers for this value. Similarly, for envelope No 3 (weight of envelope, 80 grams, plus weight of hydrogen, 35 grams; height of ascent with expansion, 10 kilometers; diameter for this height, 120 centimeters), we find a balancing height of 18 kilometers.

For envelope No 50 (weight of envelope, 360 grams, plus weight of hydrogen, 270 grams; height of ascent with expansion, 10 kilometers; diameter for this height, 230 centimeters; weight of radiosonde, 1,100 grams), we obtain lift of 1 cubic meter of hydrogen required for balancing of $\frac{(630+1,100}{6.5} = 266$ grams, which corresponds to a height of 13 kilometers, or, for the case of ascent without load, 630/6.5 = 97 grams, which corresponds to 19 kilometers.

Envelopes of the 5th category differ from those just considered only in that the pilot balloon will balance more rapidly when an airhole forms. Consequently, the maximum heights of ascent will be considerably lower. In addition, the time of "suspension" will be considerably less, so that the fictitious heights will also be smaller.

Generalizing the preceding, we reach the following conclusions:

1. The maximum height of ascent of the very best types of large ideally elastic envelopes made from natural and synthetic latex does not exceed 35 kilometers.

2. Maximum height of ascent: the best fresh samples of latex seamless envelope No 1 has 6 kilometers, envelope No 2 has 15 kilometers, envelope No 3 has 20 kilometers, and envelope No 50 (without a radiosonde) has 20 kilometers.

3. The heights of ascent mentioned in the beginning of the article are fictitious.

4. Fictitious heights, which are obtained only in one-point observations, depend upon the length of observations, which (length) depends upon the following:

a. (1) the amount of wind drift of the balloon and (2) the visibility (for envelopes balancing "stiffly" in air);

b. (1) the height at which the air hole formed, (2) the strength of the envelope, (3) the amount of gas escaping, (4) the wind drift of the balloon, and (5) visibility (for envelopes with air holes).

From the computations cited, we conclude that as long as the maximum stretching coefficient is considered to be the limiting factor in designs and producion technology, the ceiling will be limited to 35 kilometers for good large envelopes. The ceiling could be almost doubled if we could obtain a combination of elastic expansion in the beginning and a rigid state at the end, since this would provide ascent until free lift completely disappears. Calculations show that envelope No 2 could have a ceiling of 13 kilometers instead of 5; envelope No 3, 18 kilometers instead of 10; and envelope No 50 (without load), 19 kilometers instead of 10.

In many cases, observations stop because the envelope is lost against the background of the horizon. In these cases, observations stop before the balloon bursts and therefore the problem of producing highly-elastic envelopes is academic.

SECRET

SECRET

STAT

Many researchers have experimentally studied efficient selection of envelope colors for various sky conditions. All of these were more or less unanimous in their conclusions, and so we make reference to only one study.

Thomas gave the following table in his article "Visibility of Colored Suspended Objects in Pibal Observations" (The Meteorological Magazine, Vol 62, 1927).

| Sky | Color of Envelopes |
| --- | --- |
| Clear Blue | Red for low cloudiness<br>White up to 2.5 kilometers<br>Silver for altitudes about 2.5 kilometers |
| White | Red |
| Light-Gray | Red or White |
| Dark-Gray | Red or White |

S. I. Troytskiy pointed out that in addition to the color the glass or luster of the envelope surface is important.

The American Dewey and Almy Chemical Company produces envelopes in three colors: black, red, white. The plant of the GUGMS has produced experimental sets of different-colored envelopes, but, unfortunately, mass production of colored balloons has not been organized.

In closing, we mention that the maximum height of ascent is a function of the degree to which the envelope is filled with hydrogen as well as of the stretching coefficient, strength, and visibility. This factor can be neglected, however, since more or less standard norms for filling are used at all stations.

- E N D -



SECRET

SECRET

Sanitized Copy Approved for Release 2011/08/17 : CIA-RDP80-00809A000600340153-4